

High-Resolution Multibeam Deepwater Cable Route Survey in High-Relief Seafloor Area

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Abstract - In support of monitoring for nuclear tests, a Hydroacoustic Data Acquisition System (HDAS) monitoring system is to be installed at Ascension Island. The system consists of two hydrophone arrays linked by fibre optic cable to the island. A survey to select cable routes from PanAm Beach on Ascension Island to the proposed hydrophone sites was conducted in the summer of 2002. The survey utilised various acoustic sensors, single beam and multibeam echo sounders, sidescan sonar and sub-bottom profilers, operating from very shallow, near surf-zone depths, to full ocean depth. Backscatter data was included in the multibeam echo sounder data acquisition. The survey employed a small survey launch for the shallow water work, depths less than 100 meters, and a 1200-ton survey ship for the deep-water work. A land survey of the beach and a diver swim survey in the surf zone, completed the end-to-end survey. Data were processed in near real time to allow for rapid assessment and revision of the survey route.

I. INTRODUCTION

In support of monitoring for nuclear tests, a Hydroacoustic Data Acquisition System (HDAS) monitoring system is to be installed at Ascension Island, a mid-Atlantic volcanic island (Fig. 1). The HDAS consists of two hydrophone arrays linked by fiber optic cable to the island. A survey was conducted in the summer of 2002 with the purpose of selecting cable routes from the shore facility at PanAm Beach, Ascension Island, to the proposed hydrophone sites offshore from Ascension Island.

The shore facility, the terminus of the fiber optic cables, is located at PanAm Beach, Ascension Island. The two hydrophone arrays are to be located ~35 km northwest of Ascension Island on what was thought to be a spur off the island, and on a seamount 110 km south-southwest of the island (Fig. 1). Aside from the geographic locations of the arrays, the other criterion for their placement was that their anchors should be in

water depth between 500 and 2000 meters. In addition to surveying and finding favorable routes for the cables, the survey was also intended to select suitable sites for the hydrophone arrays.

The survey work was managed and overseen by personnel from the United States Air Force (USAF) Technical Applications Center (Melbourne, FL), the United States Navy (USN) Naval Facilities Engineering Service Center (NFESC; Port Hueneme, CA) and from Sound and Sea Technology, Inc., and carried out by Thales GeoSolutions (Pacific), Inc. The USN Underwater Construction Team 1 (UCT-1) and USAF personnel on Ascension Island provided support during the survey operations. Logistics support, transportation for survey equipment and personnel to Ascension Island, was arranged by the USAF Technical Applications Center.

The land survey extended from the shore facility at the north end of PanAm Beach to the low water line. Three possible cable landing sites were considered and surveyed.

The inshore survey extended from the shore to about the 50-meter isobath. The seabed survey was carried out using a single beam echo sounder, a dual frequency sidescan sonar and a 3.5 kHz shallow sub-bottom profiler. A near-shore diver survey was also carried out to assess the characteristics of the seabed near the surf zone. The inshore survey consisted of an area approximately 1.8 km² in size, being about 1.5 x 1.2 km, covering the entirety of Southwest Bay and PanAm Beach.

The offshore survey extended from about the 30-meter isobath to the proposed locations of the acoustic monitoring arrays. One array is located approximately 35 km northwest and the second is 115 km south-southwest of Ascension Island. The offshore survey

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consisted of acquiring multibeam bathymetric data, including backscatter strength, and shallow sub-bottom data in order to characterize the seabed and identify suitable routes for the cables. The offshore survey consisted of two corridors, one about 39 km long and the other 120 km long (Fig. 2) connecting to 20 X 20 km area surveys at each of the proposed hydrophone locations.

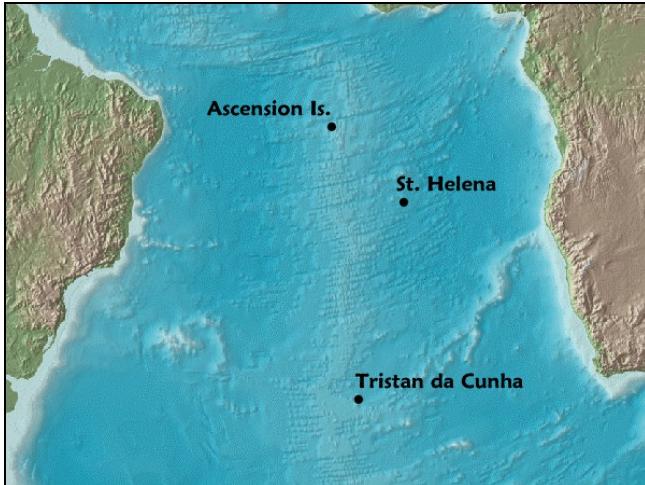


Fig. 1 The location of Ascension Island

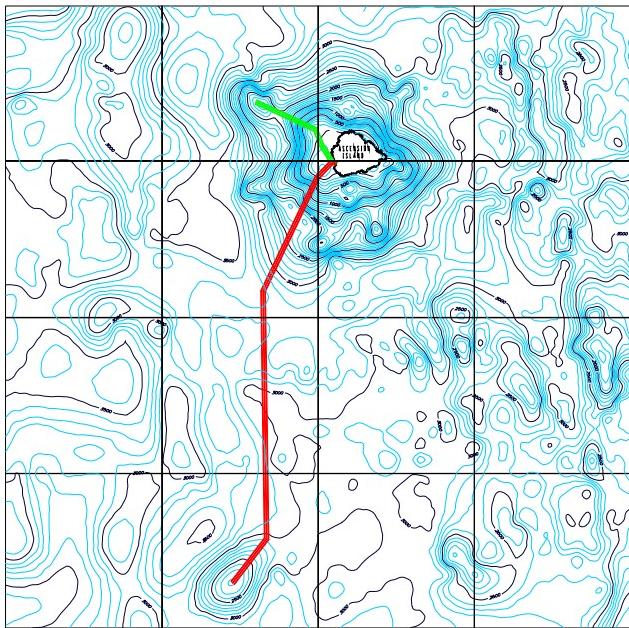


Fig. 2 Proposed NW (green) and South (red) Survey Corridors (pre-survey bathymetry taken from desk-top study).

II. THE SURVEY

A. Landing Site Survey

The landing site survey spanned the entire length of PanAm Beach (Fig. 3). A shore facility at the north end of PanAm Beach would serve as the cable terminus. At the time of the survey, three possible cable landfalls were under consideration. Site Alpha was located on a rock outcrop at the northern end of PanAm Beach, 100 meters west of the shore facility. Site Bravo was at the southern end of the beach, also on a rock outcrop, about 630 meters from the shore facility. Site Charlie was located on the beach itself, about 80 meters from the shore facility.

The land survey was carried out using a Sokkia Total Station and a GPS RTK system. Two local GPS monuments were established in the area using stand-alone GPS systems. One system was installed adjacent to the shore facility (Fig. 4) and the second at a concrete block about 500 meters south of the facility (Fig. 5). These monuments were tied to existing monuments on the island using a GPS RTK system.

An additional function for the land survey was to establish an RTCM base station for use in the inshore survey. The RTCM transmitter was located at the shore facility and provided differential GPS corrections to the inshore survey vessel.



Fig. 3 PanAm Beach and Southwest Bay



Fig. 4 Location of the shore facility GPS Site.



Fig. 5 Location of the second GPS Site.

B. Diver Swim Survey

Members of UCT-1) carried out the diver swim surveys. The diver surveys spanned 450 meters, typically extending about 550 meters from the proposed BMH locations. The intent of the cable installers was to directionally drill out from the proposed BMH location and diver video was obtained up to the proposed underwater exit locations.

For each diver survey, a distance-tagged, 450-meter long lead line was deployed along the proposed cable route. The lead line was positioned using a combination of the onshore (land) survey and the DGPS system on the inshore survey boat (M/V Range Rider). The divers used a digital underwater video camera to obtain a record of the conditions on the seabed along the proposed cable routes. At 50-meter intervals along the lead line the divers probed the seabed with a meter long stainless steel rod, assessing

the depth of sediment. The visibility was typically 25 meters or better, giving an excellent record of the seabed directly along proposed cable routes.

C. Inshore Survey

The inshore survey entailed surveying the entire area of Southwest Bay, from as near to shore as the vessel could safely operate to approximately the 50-meter isobath. The survey plan consisted of approximately shore-parallel survey lines that covered the area of the bay, and provided over 200% coverage (sidescan sonar) of the seabed. Two days were required to complete the area survey. On the third day the survey data were fully processed and a preliminary analysis was carried out. Based on the findings, cable routes for the shallow water regime were selected and additional survey lines were run along these proposed routes.

The inshore survey was conducted aboard the M/V Range Rider (Fig. 6), a local 14-metre fiberglass sport fishing boat. The M/V Range Rider was outfitted with a Novatel GPS system and Thales GeoSolutions' WinFrog navigation system. Differential corrections were supplied via radio modem by a temporary RTCM system established onshore. Vessel heading was determined using a KVH-1000 magnetic compass. A single beam echo sounder and a 3.5 kHz sub bottom profiler were mounted on masts fitted to the port and starboard side of the vessel. A sidescan sonar was towed behind the vessel, and was managed using a manual winch. The position of the sidescan sonar towfish was estimated using measures of the cable scope. A "dog-on-a-leash" algorithm was used to estimate towfish position, and this estimation was verified by examining overlapping, reciprocal course, survey data. All data were logged digitally and were processed daily at a temporary shore facility.



Fig. 6 M/V Range Rider

D. Offshore Survey

The offshore survey entailed surveying from the 30-meter isobath in Southwest Bay to each of the two proposed hydrophone locations. The survey plan consisted of acquiring data along proposed cable routes to the two hydrophone sites, conducting a 20 X 20 km area survey at each site, and then, depending on the findings, explore alternative sites and routes as the survey vessel returned to the island.

The R/V Baruna Jaya III (Fig. 7), a 61-metre research vessel, was used for the offshore survey.



Fig. 7 R/V Baruna Jaya III

The R/V Baruna Jaya III was equipped with the following primary equipment for execution of the survey:

- Reson SeaBat 8160 Multibeam Echosounder (MBES), hull mounted
- Simrad EM12D MBES, hull mounted
- GeoAcoustics GeoPulse Sub-bottom Profiler System (model 5430A / 5210A), hull mounted
- TSS Heading and Dynamic Motion Sensor 220
- TSS Dynamic Motion Sensor (DMS) 2-05 and TSS/SG Brown Meridian Surveyor Gyrocompass
- Trimble GPS antenna, SkyFix MiniDome and MultiFix III for Differential GPS positioning
- Triton Erics International (TEI) Isis Sonar, DelphMap, DelphSeismic & BathyPro Software Suite
- Thales GeoSolutions' Winfrog Navigation
- CARIS HIPS for bathymetry processing
- TEI DelphSeismic for SBP processing

In addition, an RTCM receiver was used to acquire the RTCM signal being broadcast from the temporary base station established for the inshore survey. This allowed for a direct linkage and crosscheck between the land survey, the inshore survey and the offshore survey, ensuring that all were tied together to provide seamless coverage over the entire survey.

The two MBES systems, the Reson 8160 and Simrad EM12, were used to acquire bathymetric data for water depths between 30 and 1200 meters, and 800 to 4000 meters, respectively. This provided overlap between the inshore survey, the Reson and the Simrad data sets. In addition to the bathymetry data, both MBES systems logged the backscatter strength data. The sub-bottom profiler was used in water depths to 1000 meters.

Data were processed daily and charts were produced. The processed data, typically in the form of images, and the charts were used to select possible hydrophone sites and assess the cable routes. These data were then used in survey planning, suggesting additional areas along the routes to survey that might provide better conditions for the cables.

III. DATA PROCESSING

All the survey data were processed digitally in the field with typical turn around of less than 24 hours. In addition to providing QC, the processed data directly influenced the course of the survey. As alternative landfalls, nearshore routes, offshore routes and hydrophone sites were selected the survey plan was modified to accommodate these changes. Preliminary charts were produced that included bathymetry, seabed gradient, isopachs and seabed imagery (mosaics).

The inshore and land survey data were processed using a temporary shore facility. The offshore data were processed on board the R/V Baruna Jaya III. All data were subsequently checked, processed and charted at Thales GeoSolutions' San Diego office.

A. Bathymetry

Inshore bathymetric data consisted of single beam echo sounder data. These data were logged by the WinFrog system. The echo sounder data were cleaned and merged with the navigation data using Thales GeoSolutions' RIBBIT data analysis program. The resultant XZY data were contoured using Quicksurf software and plotted in AutoCad. The MBES data were processed using CARIS software and plotted using a combination of AutoCad and Thales GeoSolutions' Chart-X software. In addition, ER Mapper software was used for display and data enhancement, such as seabed gradient images.

Fig. 8 shows the shallow bathymetry. Fig. 9 shows the same area with the data processed to highlight seabed gradients. The gradient image depicts the seabed slope in pseudo-color with blue representing very gentle slopes while red represents a slope greater than 50%.

The nearshore data, gridded at 5 m, show a series of terraces descending from the island with steep slopes associated with rock outcrop fingers.

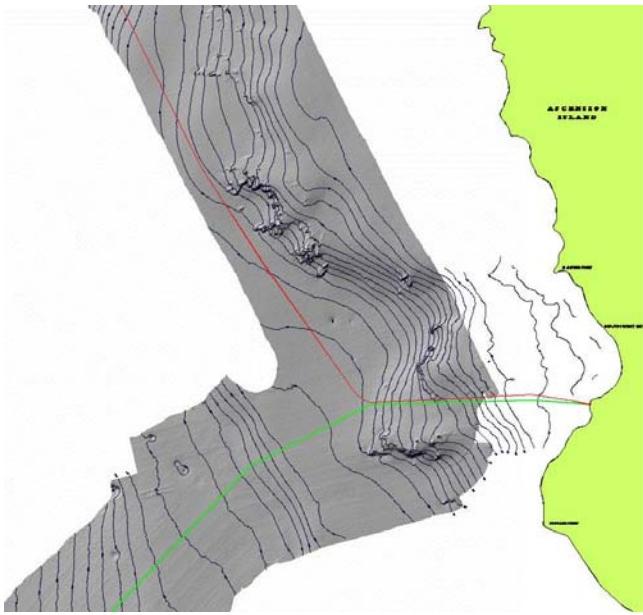


Fig. 8 Shallow Bathymetry – Sun-illuminated MBES data overlain with 5-meter contours. The proposed cable routes are shown.

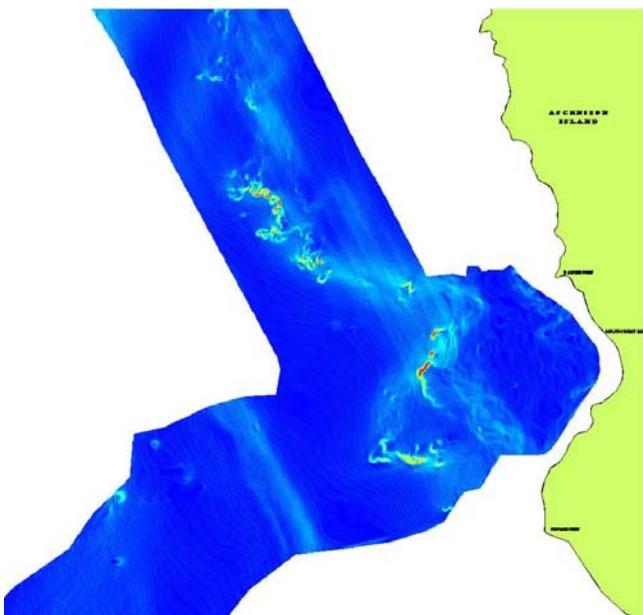


Fig. 9 Shallow Bathymetry – Gradient image (blue – 0% slope; red - >50% slope)

Fig. 12 shows a portion of the offshore bathymetry data in the area of the seamount. Fig. 11 shows the seabed gradients of the same area. Fig. 13 shows the bathymetry for the entire survey area, including the seamount south of Ascension Island and the volcano to the northwest. **Error! Reference source not found.** shows the seabed gradients over the entire survey area.

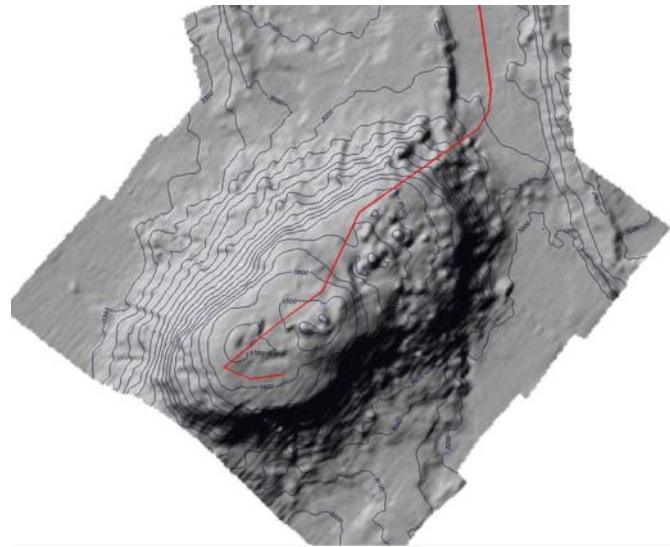


Fig. 10 Seamount bathymetry – Sun-illuminated MBES data overlain with contours at 20-meter intervals. The proposed cable route and hydrophone locations are shown.

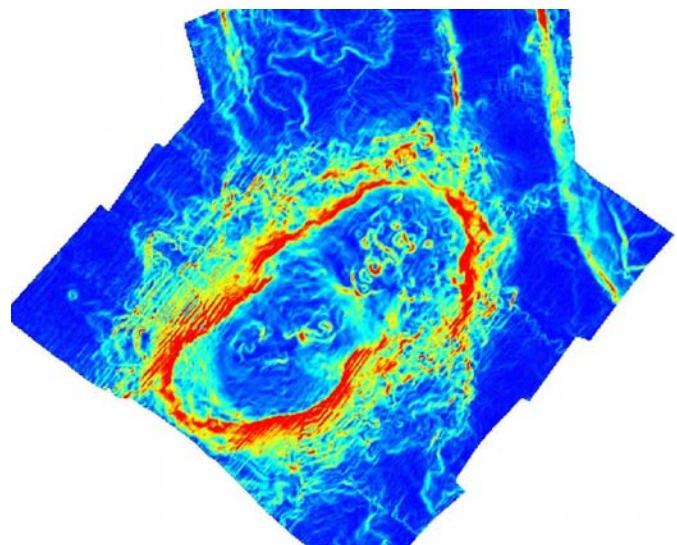


Fig. 11 Seamount bathymetry – Gradient image (blue – 0% slope; red - >50% slope).

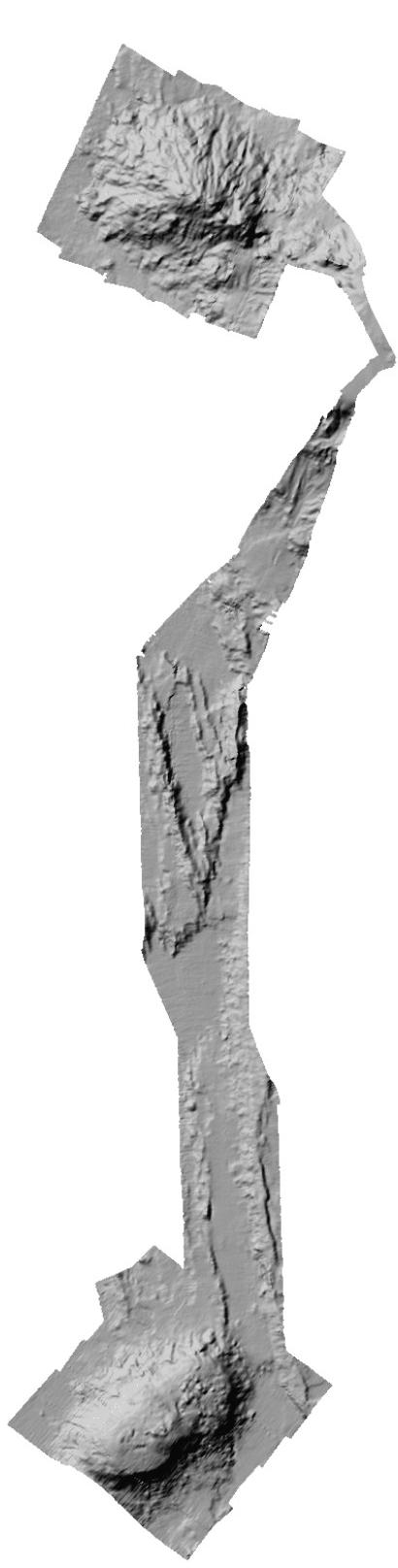


Fig. 12 Offshore bathymetry

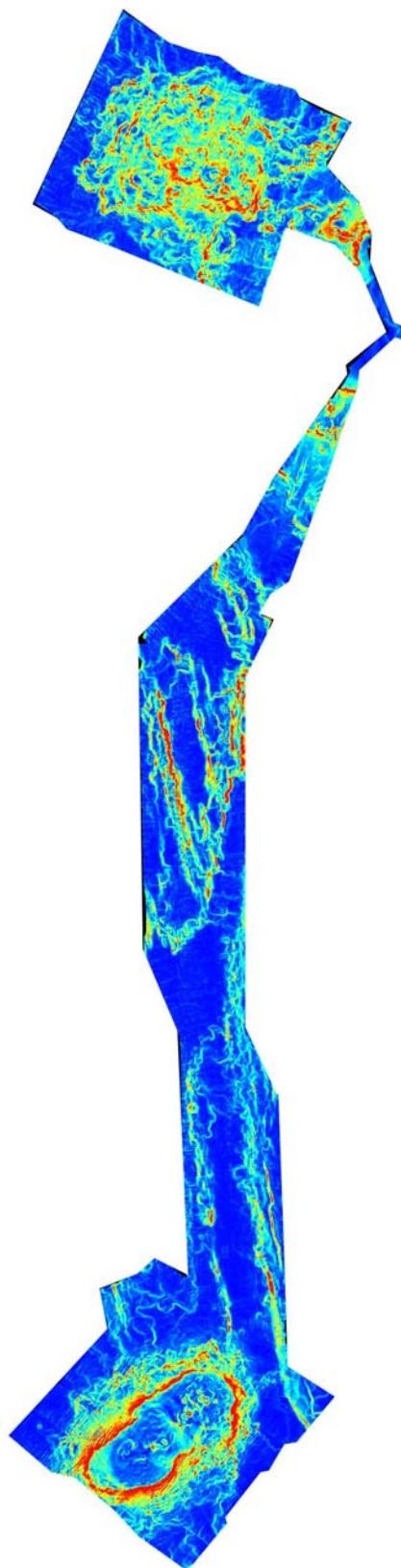


Fig. 13 Offshore bathymetry – Gradient image (blue – 0% slope; red - >50% slope)

B. SEABED IMAGERY

Inshore sidescan sonar data were logged on a TEI ISIS system in XTF format. Navigation data were merged with the sonar data and the data were geocoded and mosaiced using ISIS and DelphMap software. Pixel size for the mosaic was 0.25 m. The sidescan sonar mosaic of Southwest Bay (Fig. 14) shows the nearshore rock areas at the north and south ends of PanAm beach. The data extend into the surf zone along the beach. A band of low reflectivity seafloor is found along the base of the nearshore rock and beach areas, while offshore one can see rocky outcrops.

The mosaic was imported into AutoCad and merged with the other survey data, e.g. bathymetry contours, land survey data, etc. This allowed for a near-real-time comprehensive analysis of all the data over a wide range of areal resolutions.

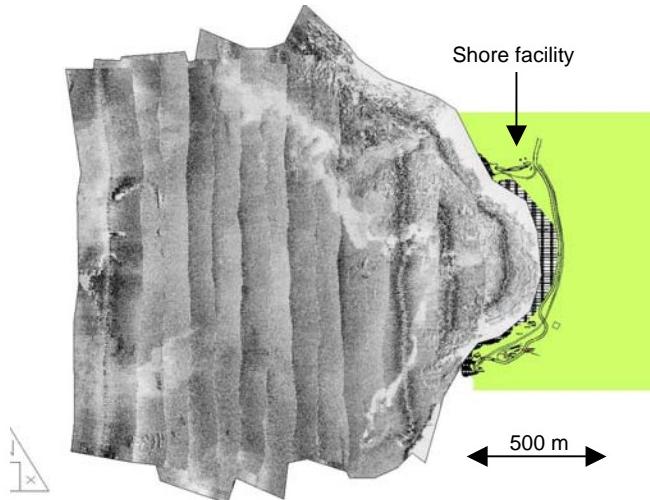


Fig. 14 Sidescan sonar mosaic of Southwest Bay

During the offshore survey, Reson backscatter data were logged by an ISIS system in XTF format. The Simrad backscatter data were logged by the Simrad MBES controller in Simrad's ALL format and subsequently converted to XTF format. The backscatter data were geocoded and mosaiced using TEI's ISIS and DelphMap software. The backscatter data from both MBES systems were corrected for across track gain variances. The corrections were made to account for changes in MBES settings during acquisition due to changing water depth. Pixel size for mosaics varied from 2 to 25 meters, depending on water depth, to allow on-screen interpretation at the best resolution available.

Fig. 15 shows the seabed backscatter mosaics derived from the Simrad EM12 data.

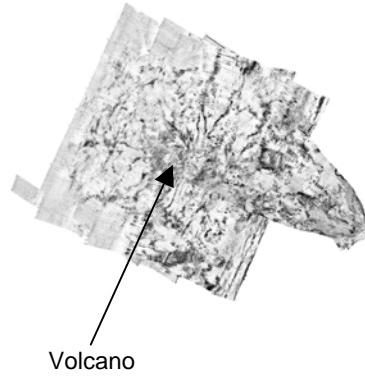


Fig. 15 Simrad EM12 MBES backscatter mosaic

Backscatter data from both MBES systems were terrain-corrected in the ISIS software. ASCII XYZ files of generated DTM grid nodes provided by the bathymetry processing in CARIS were imported into the BathyPro software and a DTM generated. The DTM was then used by ISIS and DelphMap when the backscatter data were mosaiced. This work was carried out in Thales Geosolutions' San Diego office.

C. Sub-bottom Profile Data

Sub bottom profiler data were processed using TEI's DelphSeismic and SeismicGIS programs. Geo-encoded sub-bottom images were then created by DelphSeismic and viewed in SeismicGIS in concert with the sidescan sonar and MBES backscatter mosaics.

Fig. 16 shows an example of SBP data from the inshore survey. These data are from a survey run along route Alpha-south proceeding from northeast (left) to southwest (right) and show rock outcropping with the rock descending beneath a sandy seabed in about 60 meters water depth. The horizontal lines indicate 10 ms, or about 7.5 meter, vertical spacing while the vertical lines indicate 10-second (nominally 35-meter) along-track spacing.

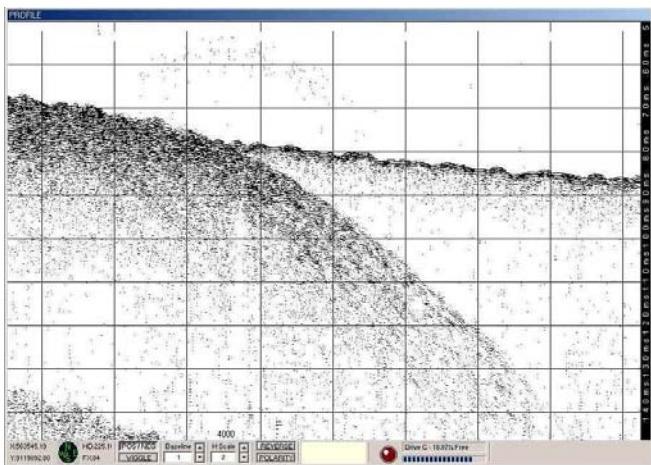


Fig. 16 An example of SBP data from the shallow water survey.

D. Charting

The majority of the charting was carried out using Thales GeoSolutions' Chart-X software. For final production, all charts were converted from Chart-X format to AutoCAD DWG format. In AutoCAD, raster images were inserted, including backscatter mosaics, sun-illuminated bathymetry and sub-bottom profile images.

During the survey products generated included preliminary charts containing:

- Sun-illuminated bathymetry images as Geotiffs, screen grabs and paper charts, at scales and resolutions dependent on water depth.
- Contour charts, merged with various images.
- Slope diagrams in which gradients were depicted as pseudo-color images.
- Backscatter mosaics at best resolution, dependent on water depth.

IV. RESULTS

Representatives of the USAF Technical Applications Center, NFESC and the cable installer met at the Thales GeoSolutions' San Diego office about one month after the survey was completed. Final Route Position Lists for both cable routes were selected, utilizing all the available data, with Thales GeoSolutions' Cable Analyst software. The landing site selected and the beach manhole (BMH) for both routes is located at the southern end of PanAm Beach. The locations of the three-hydrophone array elements for each of the segments were also included in the selection process.

Near shore the cable routes enter a drilled conduit through volcanic rock at the BMH and emerge in coarse-grained sediment approximately 150 meters west of the BMH in about 12 meters of water. Diver videos show that the near shore volcanic rocks exhibit a blocky, angular texture typical of AA lava. This rock is very abrasive and diver videos show cable faults along existing split-pipe encased MILS cables at the north end of PanAm Beach. The coarse-grained sediments through which the cable routes emerge consist of pebbles and cobbles. This gravelly area has patches of light colored finer-grained sediment, which is likely carbonate sand accumulations that give the seafloor a mottled appearance.

The cable routes approach a break in slope about 400 meters from the BMH. Sub-bottom and sidescan sonar data suggest this slope consists of rock outcrops, most of which are covered by gravel. The routes cross an area of exposed rock before continuing down this slope, followed by gravel and then finer-grained sediment in a well-defined channel between rock outcrops. The sub-bottom data show a range in sediment thickness of 1 to 7 meters throughout the nearshore survey area.

The two routes diverge approximately 155 meters from the BMH

From the nearshore survey area, the northern survey corridor continues to deepen to the north by northwest. The route crosses through areas of rock, scattered rock, slope or channeled debris, and finer and coarser-grained sediment areas. At about 11 kilometers from

the BMH, the cable route is directly above a dramatic increase in slope and nearly parallels a prominent northwest trending rocky ridge. Regional bathymetry obtained from sources other than the survey suggests that this ridge is a more significant geomorphic feature than alluded to in the survey data. The seafloor deepens from the northwest trending ridge to a saddle and then abruptly shoals to a very large submarine volcano. The summit of the volcano is craggy and is elongated in a northwest fashion in direct trend with the ridge. The volcano has a basal diameter of approximately 16 kilometers in water depth of about 3600 meters, and its summit is at about 800 meters water depth. The original location for the hydrophone array was on what was believed to be a ridge extending out from the island. However, the survey revealed the submarine volcano, and the hydrophone location chosen is on the relatively flat saddle between the island and the volcano.

The southern cable route heads west from the nearshore area. The route continues to deepen along the Ascension volcanic edifice, crossing steep slopes and northwest trending slope-parallel rock outcrops. The route meanders through these rock outcrops along

areas of least slope and roughness (as assumed from the backscatter image data). The base of the island is reached at about 3500 meters water depth, approximately 35 kilometers from the BMH. South of the edifice, the route crosses a series of north by northwest trending rock ridges that extend from the base of the island to the south. The route traverses a 3 km-wide depression between rock ridges, followed by a second area of rock ridges, this time about 5-km wide, before reaching the seamount. The base of the seamount, a 19 X 9 kilometer oval structure, is in approximately 3200 meters water depth. The seamount is steep sided and nearly flat on top, with craggy outcrops interspersed with several sediment pools. Debris slopes are found around the seamount. The cable route ascends the seamount at its northeastern end, where the gentlest slopes are found.

Acknowledgments

The assistance of members of UCT-1 with all aspects of the inshore survey operations is greatly appreciated. Thanks are also due to USAF Ascension Island personnel for logistics support.